

**A GUIDE TO THE TEACHING  
OF CLINICAL RADIOLOGICAL PHYSICS**



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**A GUIDE TO THE TEACHING  
OF CLINICAL RADIOLOGICAL  
PHYSICS  
TO RESIDENTS IN RADIOLOGY  
1982**

Committee on the Training of Radiologists  
American Association of Physicists in Medicine

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TO RESIDENTS IN RADIOLOGY - 1982

American Association of Physicists in Medicine

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PREFACE

This publication is intended to be a teaching guide, useful to all those involved with providing quality instruction in clinical radiological physics to residents in radiology and is intended to be used in conjunction with the American College of Radiology Syllabus and Problems in Physics for Radiology Residents.<sup>1</sup> Any comments or suggestions concerning this Guide should be directed to the Committee on the Training of Radiologists, American Association of Physicists in Medicine.

## INTRODUCTION

Over the past few years several events have taken place which have had a significant impact on the teaching of clinical radiological physics to radiology residents. Technology in the field of clinical imaging has been growing rapidly with new modalities being introduced and significant changes being made in presently available imaging systems. The practice of radiology has been divided into two divisions with several subspecialties, and therefore more intensive study is required. Support for physics has increased, e.g., AAPM total membership is up from 888 in 1973 to 1,717 in 1978. Finally, the clinical radiological and radiological physics communities have come to realize that both the content and the method of presentation of physics courses for residents need updating and upgrading.

This report is an attempt to provide guidance to all those concerned with providing quality clinical radiological physics instruction to radiology residents: program directors, teachers, and hospital administrators. It is hoped that this Guide will find its way into the hands of all these people in every program.

To this end, this report provides information that will assist in promoting the atmosphere for establishing quality training programs and indicates some teaching techniques. A very concerted, continuing effort is being made to ensure the relevance of the "Boards" to the practice of radiology and the relevance of our teaching to both.

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#### A. PHILOSOPHY FOR THE TEACHING OF CLINICAL RADIOLOGICAL PHYSICS TO RADIOLOGY RESIDENTS

The rationale for including clinical radiological physics in radiology residency curricula is that the practice of radiology depends to a significant degree on the appreciation for and application of physical principles as they pertain to activities in which the radiologist has the prime responsibility, is the lone actor, or is the critical factor. These activities include evaluation of image quality for optimum information (diagnosis); evaluation of efficacy of treatment (therapy); patient and staff safety; economical and efficacious choice of equipment; and facility design.

The physicist understands the term "physics" as that branch of science that deals with fundamental quantities. It is clear that the radiologist needs something else (namely that embodied in the term "clinical radiological physics") in order to carry on meaningful discourse with other radiologists, radiologic physicists, technologists, service engineers, and salesmen. It may be that some or all of these people will finally answer the radiologist's questions, but the radiologist must be able to ask the appropriate questions.

Radiologists should, by their knowledge of clinical radiological physics, be able to bridge the gap between physics and medicine without themselves having to become radiologic physicists.

It is important to stress that a residency is primarily a professional training and not a continuation of academic studies; therefore, clinical radiological physics should be practical and pertinent to the practice of radiology. Put succinctly, the clinical radiological physics curriculum should be very much goal oriented. The resident should be taught the clinical radiological physics that a radiologist must know in order to satisfy the needs of the patient in terms of the medically pertinent technical knowledge, the economics of health care, and the safety of all.

#### B. STATEMENT TO PROGRAM DIRECTORS AND ADMINISTRATORS

The appropriateness of important decisions made by radiologists concerning such issues as equipment specification and selection, facility design, patient and staff safety, and efficacy in diagnostic or therapeutic procedures will depend on his or her

application of a wide range of subjects in clinical radiological physics. In radiology, now as never before, the techniques are becoming increasingly complicated, the equipment is complex and expensive and concern for safety is ever present. It is the purpose of the clinical radiological physics portion of the residency programs to prepare physicians to meet these problems in their practice.

The essential topics published by the American Board of Radiology (ABR) reflect a renewed interest in teaching appropriate material to radiology residents, and the success of that teaching depends to a critical extent on the establishment of a good learning atmosphere.

Any new radiology residency program, and those that are already established, should look carefully at the allocations of space, time, equipment, and manpower needed to achieve the goals defined by the physics teacher. Although, it is not possible to make detailed statements that are applicable to all programs, some general recommendations can be made.

The didactic teaching of clinical radiological physics must be carried out at a time of day and under circumstances that are conducive to learning. Attendance at classes should be mandatory. Residents should not be "on call" during class. The instruction in clinical radiological physics should warrant the same consideration as any other aspect of the program. Quite clearly, the attending staff may have to "cover" so that the residents can obtain their physics training. To allow clinical radiological physics to be taught only when residents have "nothing more important to do" is to undermine the entire effort in terms of its relative importance and the efficacy of the teaching.

The 1978 survey by the American Association of Academic Chief Radiology Residents indicated that the average program in diagnostic radiology is devoting about 46 lecture hours per year to the teaching of physics. A minimum of 200 hours is required for certification by the Nuclear Regulatory Commission (NCR) including lectures, laboratory experience and demonstrations. This same number should apply to diagnostic radiology, therapeutic radiology and nuclear medicine.

It must be appreciated that a very significant part of the physicist's time may be occupied with teaching. It is commonly accepted that for every 1 hour of class time, 2 hours should be allowed for preparation.

There must be support for, and reinforcement of, the teaching of clinical radiological physics from the program director and the clinical staff. The program director should review, with the physics instructor, the clinical radiological physics program on a regular basis. In addition, the program director and members of the clinical staff should participate in a clinical radiological physics training program, if only in a modest way.

The residents who are taking the clinical radiological physics course should be tested and their status in the program

should be made contingent on satisfactory performance, as is the case in their clinical areas. The expectations of the program director and the methods of evaluation should be clearly defined at the start of the program.

Careful consideration must be given to choosing the person who is to do the teaching of clinical radiological physics.

#### C. QUALIFICATIONS OF INSTRUCTORS

It is generally assumed that one who has been a good physics student will also be a good physics teacher. This is not necessarily so. Although, it is common practice for physicists to take academic jobs where they must teach physics to students who are well motivated to become physicists, it is another matter to teach clinical radiological physics to adults who are not motivated, are often distracted by clinical situations, etc. Thus, the person who is selected to teach clinical radiological physics to radiology residents should be a Board Certified physicist or other individual having extensive background in clinical radiological physics, instrumentation and safety, and should be chosen especially with his/her teaching ability in mind.

At this writing there are no standards for this type of teacher training, and no specific education courses are directed toward preparation for the teaching of medical physics to physicians. Until such time as teaching skills become part of radiologic physicists' own curricula, we must rely on such expedients as local teachers' colleges, adult education, special symposia, tutorials, the constructive criticism of one's students and peers, and self-study.

In many cases, the medical physicist must teach a wide variety of persons, including nurses, technologists, medical students and residents, as well as physicians and other physicists. This means that the program director, in selecting a teacher, must either consider prior teaching training or proven experience, or be prepared to subsidize the acquisition of such training.

#### D. COURSE ORGANIZATION

The organization of a course in clinical radiological physics must meet several criteria:

1. It must catch and hold the sincere interest of the student.
2. It must impart relevant information in an easily assimilable way.
3. It must fit into the total program in an appropriate way.

Before some positive recommendations are made, it is necessary to state one caveat: the essential topics prepared by the ABR are not intended as a scheme for course organization. This



is simply a list of topics that the ABR believes at this time to be relevant. The organization of these topics into an effective, cohesive course is left to the teacher. Also, not all topics listed merit the same intensity of instruction.

Several definite recommendations can be given to help achieve the above criteria. The overall program of clinical radiological physics should be as intensive as possible, and as much as possible of its content is best given early in the program. The contact hours cited in section B are intended only for perspective. One should not be overly concerned with clock hours but rather emphasize the success of the program. If 220 hours is the goal, these should be apportioned heavily toward the beginning, and formal classes should be relatively rare toward the end of the program. By the end of the program the physicist and residents should be working together.

#### 1. Introductory Course

There should be a brief introductory course soon after the new resident has entered the program. If such a course is effectively presented, a resident will have acquired a useful working knowledge, be prepared to speak and listen intelligently to physicists, technologists, and radiologists, be watchful for physical principles at work, be able to establish rapport with the physics staff early in the training period, and be better prepared for the more intensive physics courses that will follow. In fact, even if the other physics courses are to follow immediately, some sort of introductory overview is recommended to avoid having the resident enter a course whose relevance might otherwise be unclear and whose goals may seem remote. The introductory course should (1) include at least some opening remarks by the program director to establish the significance of the training in clinical radiological physics; (2) give an overview of the application of physics to the specialty; (3) be practical rather than esoteric or theoretical, perhaps even teaching some simple useful skills so that the resident may actively participate in departmental work; (4) convince the resident of the relevance of a knowledge of clinical radiological physics by making use of real-life examples of its applicability in such areas as improving image quality, decreasing patient dose, achieving equipment specification, and decreasing operating expense; and (5) establish the practical aspects of radiation safety to which the resident has not previously been exposed. This course should consist of 10 hours of orientation and 20 to 40 hours of introductory material.

#### 2. Basic Physics

It is desirable to present basic physics in separate courses for the purpose of identifying those topics that serve as the physical basis for the more clinically related physics and the technical aspects of the later courses. It also facilitates systematizing the topics into a core physics course for multiple specialty programs (with appropriate specialized outside reading). Although, the basic physics courses deal with fundamental aspects of radiation and matter and their interaction, the level should be appropriate to the intended audience. Thus, theory and

mathematics should give way to plain-English explanations and relevant results and conclusions. Derivation of equations should be presented only if requested or if doing so will clarify a point. In fact, the presentation should be qualitative except for those aspects in which the resident must develop competence in actual calculation, such as the mathematics of decay. Determining how many computations in basic physics a radiologist actually does in practice will help put these matters into perspective. Such computational problems that do serve a useful purpose should be handled in a relaxed way as homework assignments. The basic physics aspects can probably best be handled in the traditional way; and if the introductory course did its job, the student will understand the need for this section of "nonapplied" information.

### 3. Clinical Radiological Physics

Although the basic physics course may present elementary principles of radiation physics in a rather classic way, it is the purpose of the clinical radiological physics courses to focus attention on the practical problems that the radiologist must be adept at solving and on developing the radiologist's ability to do so.

This is probably best achieved by identifying a number of goals or end products in which the radiologist is interested and then examining the elements that make up the whole.

Several examples may help.

1. Ask the students to state the characteristics that identify a good therapy treatment. Have them go on to specify the characteristics of a treatment machine that will produce good results in treatment. Then have them relate these characteristics to the manufacturer's specifications.

2. Ask the students to predict their future nuclear medicine practice. Have them write up a mock NRC license application.

3. Present the students with the detailed specifications of several radiographic and fluoroscopic x-ray units. Have them choose among them and give detailed justification.

The clinical radiologic physics course should contain those elements of radiation protection that apply to the specialty. The course should prepare the radiologist to administer protection schemes for patients and staff, to appreciate the problems of effective facility design, to understand the concepts of keeping exposure of personnel as low as reasonably achievable, and to understand the requirements of licensure, regulation, and accreditation.

It is not appropriate here to cite any more examples, but it is very important that the physicist/teacher clearly understands how physics fits into the role of the radiologist and then develop the course in clinical radiological physics to meet those needs.

### 4. Special Topics

There are some subjects that are not entirely clinical radiological physics but that the resident may be held responsible for by the ABR. These include statistics, physical principles of

radiobiology, computer technology, physics of vision, and information theory.

#### 5. Elective Topics

In many institutions, residents may wish to go more deeply into the required topics or to explore peripheral areas. It is not our purpose to specify what these areas might be but simply to encourage such pursuits as are appropriate in a given setting.

### E. TEACHING TECHNIQUES

Suggesting teaching techniques is an important aspect of this Guide. Although there is no substitute for a well-organized course, certain methods can make the course more effective.

#### 1. Audio-Visual Aids

Classroom time is an important part of a training program because it is a setting in which the instructor can help the student develop the appropriate concepts of clinical radiological physics. Concept formation is greatly enhanced by the use of visual presentations. Several different methods are available for presenting visual material.

Radiographic Images.--It is very important that the concepts of image formation and image quality be illustrated by the use of actual clinical radiographic images. An instructor should create a set of teaching images of actual patient cases as well as phantom or test objects.

Showing the films on conventional viewboxes offers maximum flexibility in the presentation but is practical only for small groups. Images that are on 8-inch by 10-inch film can be projected onto a screen by the use of an overhead projector. Images can also be copied onto 35 mm slides for classroom use.

Handouts.--Most medical schools make extensive use of handouts. Consequently, residents are quite attuned to this type of material and the physicist will find this invaluable in that only relevant material need be provided for the residents' reading.

Overhead Transparencies. --One of the most versatile modes for presenting visual material in the classroom is the overhead projector. In addition to projecting radiographic images, it can be used to present all types of illustrations. There are several ways of obtaining the transparencies for this mode of projection. Most institutions also have copy machines which can be used to produce transparencies from printed material. Special markers are available for drawing and writing directly on transparent sheets. These can be used to prepare illustrations before class time or during the presentation as one would use a chalkboard.

Overhead projection offers a high degree of flexibility in comparison with 35 mm slides. With the overhead projector, it is easy to go back to previous illustrations for the purpose of review, relating concepts, or answering questions.

35 mm Slides.--Both radiographic images and printed illustrations can be copied onto 35 mm slides for classroom projection. Slides are relatively inexpensive to make with either special copy

film, which can be developed in x-ray film processors, or color transparency film, which can be processed commercially. A major disadvantage of 35 mm slides is that the material must be arranged in the projector trays before the presentation. This makes it somewhat difficult to alter the order of presentation in the classroom or to refer to previously used illustrations.

## 2. Laboratories and Demonstrations

Laboratories should be part of the residents' training only when they can be used well, which means having appropriate equipment available at an appropriate time.

Laboratory experiments are useful in reinforcing basic concepts previously presented in lectures and in providing residents with important and desired hands-on experience. The important guidelines in conducting lab experiments are to have a definite, stated objective, to be brief and to the point, and to require only the absolute minimum data collection necessary to illustrate the objective. It is often desirable and useful to require the residents to think through the concept being investigated and to prepare a brief report. Following these guidelines will result in laboratory sessions that provide a meaningful learning experience for residents.

Demonstrations are also useful teaching aids. Examples are the operation of film changers and other special-procedure equipment; focal spot checks, checks on radiation and light-field congruence and their adjustment, and other quality assurance tests; and the calibration of an x-ray generator (i.e., kVp, mA, and time adjustments). The general philosophy of the guidelines discussed above for laboratory experiments should also be incorporated in demonstrations.

Although not exactly in the same category, having the residents participate in technologists' film critique sessions or act as film quality control supervisors can quickly acquaint the resident with very practical problems and solutions.

## 3. Clinical Radiological Physics Participation

Nearly all of the activities of the clinical radiological physicist are of interest to the prospective radiologist. The application of physics will emphasize and reinforce the instructional course. Working with a radiological physicist gives the resident perspective into and a sense of priorities for the application of radiological physics. It also helps clarify the position and the functional methods of the radiological physicist. The nature of the physics records and files becomes clearer by participation in their use. Perspective into certain aspects of the physical and administrative structure of the hospital may also be obtained. Finally, participation in clinical radiological physics introduces many real problems that are often not directly addressed in a didactic course. Areas of particular interest include quality control and the relationship to physical aspects of equipment, dose calculations (primarily in diagnostic radiology), and radiation safety as it pertains to the radiologist in a small

office or hospital (where the assistance of a physicist may not be readily available).

There are, of course, limitations. The coverage of topics is certainly incomplete, and major conceptual developments are usually neglected. Boredom with some of the more tedious tasks, or lack of any task, may cause an unpleasant and unproductive experience, or there may be simple communication problems. Also, it is not usually possible to organize the simultaneous participation of more than one or two residents.

The activities in which a resident could fruitfully participate include virtually all of the clinical activities of a radiological physicist and perhaps even a little research for selected residents. The calibration and safety checks of radiation producing and radiation detecting equipment is a very desirable activity for participation; also, quality assurance programs are important. The resident should have some contact with real computations in clinical radiological physics such as therapy treatment planning and diagnostic dose computations-for example, the calculation of fetal exposures. Many of the activities of the radiation safety officer are also suitable for resident participation. These include surveys, the monitoring program, shielding planning and evaluation, and many of the aspects of documentation. In addition, it would enhance a resident's understanding to observe administrative functions such as a radiation safety committee meeting or an inspection by an accrediting or regulatory agency.

The degree of participation will vary with the institution, the task, and the interests of the resident and the physicist. The most effective form from a teaching point of view is the role of the resident as a supervised student. One should not expect the resident to function as a co-worker and should remember he is a student learning new skills. With such a teacher-student relationship the highest levels of interest and understanding are likely to be obtained. For some activities the resident can only be an observer; in that case, it is important to prevent boredom and to ensure that the significance of the activity not be misunderstood. There is a need to maintain a proper professional and teaching atmosphere; the use of a resident as a full-time "go-for" is to be avoided.

The scheduling of a resident's time for participation in clinical radiological physics is often a difficult problem. Not only are there many demands on the resident's time, but suitable physics activities are often hard to schedule by themselves. Some institutions utilize a formal rotation through physics. In other cases, a portion of another rotation, such as half a day per week while the person is assigned to ultrasound, is utilized. Only in small institutions, and generally with mixed success, can residents be taught physics without a scheduled time allotment.

The personality of the clinical physicist who works with the residents during clinical participation is as crucial to the

success of this mode of teaching as to any other mode. A secretive, disorganized, or dogmatic physicist is not likely to convey much useful information or positive attitudes. An articulate, well organized individual who likes to demonstrate and discuss is needed.

Not only should the resident spend time with the physicist, but the teacher should be a regular participant in the clinical activities--not just direct patient care but also journal clubs, tumor boards, and so on, at which physics can occasionally be the subject for discussion.

#### 4. Guest Lectures

If the chief radiologist gives a lecture entitled "How I Use Physics in My Daily Practice" as the opening lecture in the clinical radiological physics course, the course will be off to an enviable start. Guest lecturers can add motivation, diversity of views, and specialized expertise, or even fill a gap in the instructor's schedule. However, because of the differences in teaching styles, personal emphasis, and terminology, guest lecturers can create chaos unless their number is limited and they are carefully utilized. If the presentation is poor, the views presented are contrary, or the subject is inappropriate, even a single guest lecturer can have a devastating effect.

The course instructor and the guest lecturer should agree beforehand in detail on the contents of the lecture. The instructor should know the lecturing style and ability of the guest as much as possible. The instructor should sit in on the lecture, both to connect the lecture to the rest of the course and to evaluate the lecturer for possible future use. The responsibility for continuity, most handouts, and the quizzes must remain with the instructor. The guest lecturer should have specific expertise and interest in the subject, a good lecturing style, and a willingness to cooperate to achieve the goals of the course.

"In-house" guest lecturers may be radiologists, other physicists, radiopharmacists, radiobiologists, biomedical engineers, or technologists. The local area may have similar persons available. Many commercial firms, professional organizations, and government agencies have lecturers on topics related to their interests. Many potential lecturers are eager to discuss those topics in which they have expertise.

The costs of a guest lecturer are usually an honorarium and travel expenses. In general, in-house and commercial lecturers will require neither; this is also often true for government lecturers. In all but a few cases, the honorarium is more token than substance. The money to support the lecturers can come from the institution's budget; unbudgeted "professional" funds may also be tapped.

#### 5. Self-Study

Under certain circumstances it may be more cost-effective to handle the physics course by way of supervised self-study. There are presently at least two major works available, both of which

require that the student participate actively in obtaining the required knowledge.

One such course<sup>2</sup> directed toward residents in radiation therapy is composed of some 30 sections that are broken down into overview and supportive information, recommended reading from "best source" references and practical exercises. Before passing on to the next topic, the student must discuss the concepts with a qualified radiological physicist.

The Radiological Learning Laboratory<sup>3</sup> utilizes a selected teaching file of radiographic films to present the principles of radiographic interpretation and also some concepts of radiation protection and radiographic imaging. It is being expanded to include more physics.

#### 6. Examinations

Examinations have several major roles in the clinical radiological physics course. The first is to provide some objective assessment of a resident's progress through the course, and in this sense the exam is essentially a teaching aid--an aid to both the teacher and the student. However, in order for exams to have their maximum educational impact they should be reviewed promptly.

The learning/teaching of clinical radiological physics is serious in the very real sense of time and manpower expended, and it is reasonable to expect the attention of the resident. Although making the clinical radiological physics course relevant to the practice of radiology is the best way of attracting the interest of the resident, there can be no doubt that relating a resident's status in the program to his or her performance in the course will also inspire interest. And just as there are undoubtedly clinically related reasons why a physician should not become a radiologist, a resident should not be allowed to continue in a program irrespective of his performance in physics. Surely examination results reported to the program director can be of some use here.

"Examinations" should not be looked at in the narrow sense, however. They can range from surprise quizzes, to end-of-course written tests, to take-home problems, to working out a solution to a problem during the clinical radiological physics rotation. We would, however, caution against the excessive use of multiple-choice questions for anything but the testing of retention of specific information. Although they are convenient testing tools for the purpose, multiple-choice tests do little to foster inductive reasoning or to pose situations encountered in real life.

Finally, a number of books are available that contain multiple choice-type material, such as the RAPHEX<sup>4</sup> examination, and these can be useful as teaching tools to help assess the resident's progress as a means of specific preparation for certification exams. The instructor should carefully review all questions and answers from commercial examination books, since some contain numerous errors.

#### F. SOURCE MATERIAL

The Committee on the Training of Radiologists (CTR) of the AAPM will maintain lists of source material in the categories listed below. The AAPM does not claim that these lists are complete; nor can it vouch for the quality of the material. Each teacher should review as much of the material as possible, not only to determine its quality and applicability to the teaching program but also to gain insight into alternative methods of presenting the same material. Caution should be exercised in that not all material will be appropriate for student consumption.

The CTR welcomes any information about these lists that will make them more accurate.

Any or all lists may be obtained by writing to AAPM.<sup>4</sup>

##### List of Source Material

1. Textbooks
2. Journals
3. Laboratory exercises and demonstrations
4. Reports
5. Audio-visual material
6. Compilations of sample questions
7. Texts on how to teach adults

#### G. ESSENTIAL TOPICS

The essential topics, as prepared by the ABR, are available from the ABR offices. Sample questions prepared by the AAPM and the ACR may be obtained from the ACR offices. The essential topics and questions are updated frequently and should not be construed as the only material that should be covered in a clinical radiological physics course. In addition, the Board does not provide any guidance, in the essentials, concerning the depth of knowledge required in each area--this is left to the discretion of the physicist-teacher.

#### REFERENCES

1. Available from American College of Radiology, 6900 Wisconsin Avenue, Chevy Chase, MB 20815
2. R. F. Moyer, Radiology (Physics), SUNY Upstate Medical Center, 750 east Adams Street, Syracuse, NY 13210
3. Prepared by ACR/BRH: available from ACR, San Francisco Office, 560 Lennon Lane, Walnut Creek, CA 94598
4. Available from AAPM Headquarters